Assessment of Fish Assemblages in Artificial Reefs of Palk Bay

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Contents

1. Introduction

An artificial reef consists of one or more objects of natural or human origin deployed purposefully on the sea-floor to influence physical, biological or socioeconomic processes related to living marine resources (Seaman and Jensen, 2000).

Artificial reefs can be submerged for the purposes of (Brickhill *et al.,* 2005), increasing fishing resources and mitigating environmental impacts (Polovina and Sakai 1989, Reed *et al.,* 2006), constituting protection for "nurseries" against illegal trawling, (Charbonnel and Francour 1994; Gomez-Buckley and Haroun, 1994; Santaella and Revenga, 1995; Lok *et al.,* 2002), enforcing "no fishing" legislation with anti-trawling reefs (Francour *et al.,* 1991; Ramos-Espla et al., 2000, Moreno, 2002), increasing biodiversity (Jensen and Collins, 1995), promoting the survival of some species (Jensen *et al.,* 2000) and promoting recreational activities, notable scuba diving and angling (Branden *et al.,* 1994). Understanding the effectiveness of artificial reefs in increasing fishery resources requires a regular monitoring of the fish assemblages living in and around artificial reefs. Fish assemblage censuses can be undertaken using destructive methods such as trawling (Bombace *et al.,* 1994), or non-destructive methods such as the underwater visual census (Bayle-Sempere et al., 1994; Charbonnel *et al.,* 1997; Bortone *et al.,* 2000; Santos and Monteiro, 2007). When artificial reefs are deployed in marine protected areas, non-destructive methods are preferred (Charbonnel *et al.,* 1997).

The loss of coastal marine habitats has been described as one of the greatest threats to the viability of commercial and recreational fisheries (Caddy JF, 2007). With the current shift in emphasis towards ecosystem based fisheries management, it is important to understand how habitat loss and habitat restoration will affect associated fish communities (Marasco *et al.,* 2007). Monitoring and assessment of artificial reefs to evaluate their effectiveness had gained great importance in recent years (Borton and Kimmel, 1991; Seaman and Jensen, 2000). More accurate description of fish fauna, abundance and biomass and monitoring of changes of these variables by yearly, seasonally and daily may provide better understanding on ecological and biological process in this structure. Artificial Reefs are assumed to function in a combination of two mechanisms: aggregation of scattered specimens and secondary biomass production through increased survival and growth of juveniles (Bohnsack *et al.,* 1994; Seaman and Jensen, 2000; ; Jensen, *et al.,* 2000; Osenberg *et al.,* 2002). Fish and invertebrates use both natural and artificial surfaces for shelter, feeding, spawning, energy economy and orientation. Their accumulation around artificial reef is a stupendous outcome of behavioral ecology. Nevertheless, a great portion of the enhanced biomass comes from materials consumed in forage areas outside the artificial reef complex. Depending on each species' association with the artificial reef and its foraging range and behavioral patterns, feeding halos are formed around the artificial reef (Carr and Hixon, 1995).

Tamil Nadu state government installed artificial reefs in ten sites along the coast of Tamil Nadu including Palk Bay. Three artificial reef sites were located in north Palk Bay region (Thanjavur District), where the reefs were installed in 2007. This study aimed to find the difference in fish assemblages in artificial reefs, sea grass and algal beds of Palk Bay by periodical deployment of bait camera video system. The findings of this study are important for future site selection and implementation of artificial reefs in Palk Bay.

2. Background and Study Area

Palk Bay, named after Sir Robert Palk (1717-1798) the then Governor of Madras Presidency (1755-1763), is situated in the southeast coast of India encompassing the sea between Point Calimere (Kodikkarai) near Vedaranyam in the north and the northern shores of Mandapam to Dhanushkodi in the south. It is situated between Latitude 9º 55’ - 10º 45’ N and Longitude 78º 58’ - 79º 55’ E. The Palk Bay itself is about 110 km long and is surrounded on the northern and western sides by the coastline of the State of Tamilndau in the mainland of India. Palk Bay and Gulf of Mannar to its south are connected by a narrow passage called Pamban Strait which is about 1.2 km wide and 3 to 5 m deep that separates the Island of Rameswaram from the mainland. The Palk Bay waters merge with those of the Bay of Bengal in the northeast and the Gulf of Mannar waters in the south. The Palk Strait is just 35 km of water that is narrower than the English channel and separates the northern coast of Sri Lanka from the southeast coast of India. Therefore the international boundary line is close to the shores of both the countries. The boundary is only 6.9 km away from Dhanushkodi, 11.5 km away from Rameswaram, 15.9 km away from Point Calimere, 23 km away from Vedaranyam and 24.5 km away from Thondi. Palk Strait lies northeast of Palk Bay between the State of Tamilnadu in India and the island nation of Sri Lanka and the width of Palk Bay ranges from 64 to 137 km (Cathcart, 2003).

Palk Bay at its southern end is studded with a chain of submerged islands or shoals which appear to connect Dhanushkodi on Rameswaram island in Tamilnadu and Thalaimannar on the Mannar island of Sri Lanka. This apparent bridge is also known as Ramasethu by the pious religious Hindus and has gained significance in recent days because of the Sethusamudram Ship Channel Project and the wide publicity created by the news media. This chain of shoals is known as Adam's bridge the name of which comes from the story that Sri Lanka was the site of the biblical earthly paradise and that it was created when Adam was expelled (Wikipedia, 2006). This bridge is approximately a 30 km long shallow ridge, with 9 km of islands and shallows and 21 km of open water, and is of Holocene conglomerate and sandstone mantled with islands and shoals of shifting sand all of which rest upon Miocene limestone (Cathcart, 2004).

The average water temperature in the Palk Bay varies from 24.6°C to 29.1°C with the lowest and the highest occurring in January and April respectively. The Palk Bay remains practically calm during most of the months. Turbulent conditions prevail during northeast monsoon period and fresh water streams dilute the sea near Mandapam. The coastline of Palk Bay has coral reefs, mangroves, lagoons, and sea grass ecosystems. The fishing season starts in October and lasts till February. Peak fishing season is during December to January. The annual average fish production is around 85,000 tonnes. The saline water and the muddy substratum coupled with seasonal rains and discharge from Vaigai and Cauvery rivers has created a good breeding ground for pelagic and demersal fishes. It can be considered as internal waters because it is in most parts land locked and is not suitable for navigation of big ships because of shoals, currents and coral reefs. The marine environment and geographical features of the region show wide variations. The areas are rich in biological diversity and have a long history of human settlement, use and exploitation. They contain diversified and productive ecosystems such as estuaries, salt marshes, sea grass beds and mangroves that are sensitive to human activities.

2.1. Hydrographic features of Palk Bay waters

Palk Bay is a shallow and flat basin, nowhere exceeding 15 meters depth. On an average the depth hardly exceeds 9 meters. The whole Palk Bay area is under the spell of both southwest and northeast monsoons. However, the southwest monsoon contributes only very little towards the annual rainfall of this area. Rainfall is moderate to heavy during October to mid-December with occasional gales. The mean annual rainfall varies from 762 mm to 1,270 mm. The monthly average atmospheric temperature varies from 25°C to 31°C with the maximum and minimum occurring in May and January respectively.

2.2. Bio-resources

Palk Bay and Gulf of Mannar are interconnected with each other not only physically but also oceanographically by way of flow of currents especially under the influence of the northeast and southwest monsoons. Therefore a vast majority of the organisms found in the Gulf of Mannar are also seen in the Palk Bay particularly those free living/moving/floating animals/plants. However, the Palk Bay lacks the habitats such as the islands found in the Gulf of Mannar which support a wide variety of corals. Otherwise, Palk Bay is as resourceful and productive as the Gulf of Mannar. Palk Bay environment is unique in the sense that it is almost an enclosed bay with input from several small rivers along its coast from Point Calimere (Kodikkarai near Vedaranyam) in the north to Mandapam in the south. The branches of the grand river Cauvery which drain through the districts of Thanjavur, Thiruvarur and Nagapattinam form a large backwater system between Muthupet and Point Calimere. The marshlands of this backwater system support lush growth of Mangrove forests which harbour a wide variety of birds both native and seasonally migratory. The backwaters act as breeding and feeding grounds for a wide variety of fin-fish and shell-fish. The enclosed nature of the bay provides protected waters that dolphins, porpoises and turtles frequent the region. Although the scientific literature available on the Palk Bay are relatively limited compared to that of the Gulf of Mannar, existing information also suggests the presence of endangered dugongs.

2.3. Biodiversity

Palk Bay is rich in biodiversity having all the important groups of flora and fauna in its environment. The total number of species and their endemic form given in parentheses are Foraminifera 51 (2), Tintinnids 12, Flora 143 (1), Sponges 275 (31), Coelentrates other than corals 123 (49), Stony corals 128 (43), Polyzoa 100 (15), Polychaeta 75 (22), Insecta 1 (1), Crustacea 651 (159), Mollusca 733 (26), Echinodermata 274 (2), Prochordata 66 (41), Fishes 580, Turtles 5, Birds 61, and Mammals 11. Among all the molluscs, though no live animals have been found, shells of Nautilus pompilius and Spirula spirula are washed ashore along the Palk Bay coast.

The study site is located in northern Palk Bay (See Figure: 33 and 34), which belongs to Thanjavur District. The artificial reefs were laid about 8km offshore of Sethubhavachattiram and Mallipattinam fishing ports. Maximum depth of the study area was 7.7m. The water visibility was poor due to strong currents and tides. High tides usually brought murky bottom waters from deeper areas into artificial site. Our study was planned to start in morning, with the start of low tide.

3. Methodology

3.1. Locating sites

The artificial reefs were selected and identified with the help of local fishers and fishery department, which is about 7.6 km from Sethubhavachattiram fish landing centre. Artificial reefs were randomly placed on seafloor, where few or more units aggregated in some areas and sparsely dispersed on sea floor in other areas (Figure: 27, 43, 44 and 45). It was difficult to search, locate and record their coordinates with scuba divers due to unorganized installation of reef units, strong currents and murky waters. The study was fixed in lowest low tide periods for better visibility. Boundary of the site was marked with Garmin etrex GPS. Adjacent sea grass beds and algal beds were also selected and marked with GPS for conducting bait video experiments.

3.2. Baited Remote Underwater Video Survey

Bait underwater camera system is a modified design from Langlois *et al*., (2006). The experimental iron frame was manufactured in local workshop. This frame was designed to hold a camera in its middle, and bait in front of the camera view (Figure: 39). A gopro underwater recording camera was fixed at the middle of the frame (Figure: 40). The camera has a capacity to record HD video for 1.30 hrs continuously. The bait was fixed at a height of 75cm from sea floor in a specially designed iron frame (Figure: 35 and 36). The bait camera system was planned to be deployed once in every month in all the three sites such as artificial reefs (A.R), seagrass beds (S.B) and algal beds (A.B). However, due to changing weather pattern, water visibility and surface sea conditions, the deployment of experimental unit was difficult (Figure: 42) was conducted only 9 months instead of 12 months. About one kg of crushed shrimps and fishes were packed in a fishing bag and used as a bait (Figure: 38). The type of bait used in this experiment and height of bait bag from the ground had influenced the number and diversity of fishes in all habitat types. So, the experiment is limited to specific height and feed type that also might be limited the fish assemblage recorded in this study (Figure: 41). The recorded video clips were transferred to external hard disk. Total number of fishes was counted from the video and individual screen shots were taken to convert into image files for measuring size using digimizer image analysis software.

3.3. Water sampling and analysis

Monthly water samples were collected during field experimental visits to record pH, salinity and temperature in Artificial Reefs (AR), Seagras Beds (SB) and Algal Beds (AB). Temperature of atmosphere and surface water was recorded by using a standard centigrade thermometer. The salinity was measured using a hand Refractometer (Atago, Japan).

3.4. Data Collection and Analysis

Fishes were identified to the lowest possible taxa. The mean abundance, mean size of all fishes were calculated from monthly sampling data, which were converted into graphical charts using excel. The multivariate analyses were performed in excel .The abundance measure of fish species at each site was calculated as the mean relative abundance for the monthly samples.

4. Results

4.1. Environmental Parameters

The physico-chemical variables of the present study areas are subjected to wide spatial and temporal variations. The rainfall is the most important cyclic phenomenon in tropical countries as it brings about important changes in the physical and chemical characteristics of the coastal and estuarine environments. In the present study heavy rainfall were received during monsoon months due to north east monsoon.

The temperature variation is another important factor in the coastal and estuarine ecosystems, which influences the physico-chemical characteristics of the coastal and estuarine waters to a greater extent triggering the breeding and spawning of marine fishes. In the present investigation, maximum atmospheric temperature was recorded during the summer season (April) with the peak of 35^{o}C (Figure: 8). The higher values of atmospheric temperature in summer and lower values in monsoon confirms the established trends along southeast coast as observed by Sampathkumar (1992), Saraswathi (1993), Ananthan(1995), Rajasegar(1998) and Vijayalakshmi(1999), Kannan and Kannan (1996), Sridhar et al., (2006).

The surface water temperature mainly depends on the intensity of solar radiation, insulation, freshwater influx and cooling and mixing of ebb flow from adjoining neritic waters. Surface water temperature shows a similar trend to the air temperature. In general, high values have been reported during the summer and lower values during the monsoon season. No profound variation was evident in surface water temperature between the three sites (Figure: 9). The gradual increase in water temperature from monsoon to summer may perhaps be due to the direct result of atmospheric condition and radiation. Similar findings have been reported from the southeast coast of India by previous workers (Nair and Ganapathy, 1983; Vijayalakshmi, 1999). In the present study high level of pH (8.2) was recorded in Algal Bed site during summer and low pH level (7.1) was recorded in artificial reef site during monsoon (Figure: 10)). However, there was no drastic fluctuation in pH.

Salinity is considered to be the prime factor among the environmental variables influencing the dynamic nature of the estuarine and coastal waters by the freshwater inflow and the prevailing temperature. It influences greatly the larval ingress, their abundance and survival. It is one of the most fluctuating one in coastal environments. Among the three sites, the salinity values ranged from 22‰ to 33‰ during the study period (Figure: 11). The maximum salinity was recorded at artificial reef site during summer and the minimum salinity was recorded at algal bed site during monsoon. This may be due to the fact that the artificial reef site is located far away from the shore and algal bed site located close to shore receive more fresh water from rivers.

The higher values of salinity recorded in summer season could be attributed to the high degree of evaporation of surface water and decreased freshwater inflow and drainage. During the monsoon seasons, all the three sites receive heavy rainfall and the freshwater input in turn greatly reduces the salinity values close to shorelines. Thus the variations in salinity is mainly influenced by the rainfall and freshwater runoff as reported by Sampathkumar(1992) and Anathan(1995).

4.2. Fish Assemblages

In fishes, 20 species belongs to 17 families were recorded in artificial reefs, 13 species belongs 11 families were recorded in sea grass beds and 3 species belongs to 3 families were recorded in algal beds (Table: 1). Apart from this, one species of carpet shark (*Orectolobiformes*) was recorded in sea grass beds. Cuttle fish (*Sepiella inermis*) and Indian squid (*Loligo duvaucelli*) were recorded in sea grass and algal bed. In artificial reef, maximum abundance (11) was recorded from the species *Terapon jarbua* (Terapontidae), where as minimum abundance (1) was recorded from four species such as *Protonibea diacanthus* (Sciaenidae), *Johnius dussumieri* (Sciaenidae), *Lethrinus nebulous* (Lethrinidae) and *Lates calcarifer* (Centropomidae), (Figure: 2). The same species *Terapon jarbua* was also abundant in sea grass beds (33) and algal beds (48). However, *Terapon jarbua* is not a commercially important fish species that is being used by small scale fishes as a bait fish. The size of *Terapon* *jarbua* is also comparatively small in all the three sites (Table: 1, 2 and 3). In artificial reefs, maximum fish size was represented by *Lates calcarifer* (80±). The cartilaginous fish carpet shark in sea grass beds was the largest size (80±) followed by *Sphyraena barracuda* and *Lates calcarifer* (53±). *Arius maculates* ((26±) was the largest fish recorded in algal bed; however the mollusk *Sepia inermis* was larger than the fish species recorded in algal bed (28±). (Figure: 1). Highest percentage of fish family was represented by *Terrapontidae* in all the three habitats (Figure 3, 4 and 5), which may due to the frequent presence of *Terapon Jarbua*, which was attracted by bait easily in large numbers.

The local fishers are catching live *Terapon Jabrua*, as they are used as live bait for catching big fishes in deep waters. Palk bay sea grass beds have been serving as a breeding and nursery ground for cephalopods. This study has proved that the number and size of cephalopods have higher in sea grass beds than algal bed, which were not recorded in artificial reef area (Fig: 6 & 7). The study found that the artificial reefs have highest number of fishes than natural sea grass and algal beds. Artificial reefs serve as a fish aggregating device for a variety of fish species that support small scale fishery. However the fish composition in artificial reefs is different from natural habitats. For example, the parrot fish *Scarus ghobban*, Red-tooth trigger fish *Odonus niger* and grouper *Epinephelus diacanthus* (Figure: 48) are not native commercial fishes to northern Palk Bay. According to local fishers, those predatory fishes were found only at artificial reefs, which also confirmed by this study. Local fishers also suggested that the parrot and grouper fishes are not preferred in local markets, and being exported to other countries. In addition to difficulties in finding commercial local markets, such assemblages of predatory fishes in artificial reefs may alter the natural food chain and ecological balance of neighboring ecosystem during large scale installation. Positive impacts of artificial reefs are the trawlers did not come close to artificial installation site, as the nets are damaged by artificial reefs. This experimental study had its own limitations such as time, equipments, weather conditions and sites. This study needs to be further improved with advanced equipments to conduct similar experiments with different types of baits in other areas of Palk Bay. However, this study is the first of its kind in Palk Bay, which used advanced digital visual equipments without harmful sampling procedures.

4.3. Statistical Analysis

Two way ANOVA test was performed to determine the interactions between the environmental parameters and fish abundance in artificial reefs, seagrass beds and algal beds separately. The coefficient of determination (R2 = 0.89 in artificial reefs, 0.99 in Seagras beds and 0.72 in Algal Beds) showed the extent to which the variability of the fish abundance can be explained by the environmental parameters (see Table: 4). This test proved that 89% of the variability can be explained in artificial reefs, 99% of the variability can be explained in seagrass beds and only 71% of the variability can be explained in algal beds. The remaining 11% in artificial reefs, 1% in seagrass beds and 29% in algal beds are random effects. It is also important to examine the results of the analysis of variance (see Table: 5, 6 and 7). The results enable us to determine whether or not the environmental parameters (explanatory variables) bring significant information (null hypothesis H0) to the fish abundance. In other words, it's a way of asking whether it is valid to use the mean of environmental parameters to describe the whole population, or whether the information brought by them is of value or not. The probability corresponding to the Fisher's F is lower than 0.603 (A.R), 0.060 (S.B) and 0.859 (A.B) (see table. It means that would be taking 60.3% (A.R), 6% (S.B) and 86.9% (A.B) risk in assuming that the null hypothesis is wrong. Therefore, the interaction between environmental variables and fish assemblages in all the sites were significant. The standardized residuals (See Fig: 12, 13 and 14) are all normally distributed.

Analysis of interaction between the environmental factors and fish abundance showed that the fish abundance in artificial reefs was high at 24^{o}C, 7.5 pH and 30ppt in salinity (Fig: 15, Fig: 16, Fig: 17, Fig: 18, Fig: 19 and Fig: 20). In seagrass beds the fish abundance was high at 27^{o}C, 7.9pH and 30ppt salinity (Fig: 21, Fig: 22, Fig: 23, Fig: 24, Fig: 25, and Fig: 26). Algal beds showed higher fish abundance at 27^{o}C, 7.5pH and 28ppt in salinity (Fig: 27, Fig: 28, Fig: 29, Fig: 30, Fig: 31 and Fig: 32).

5. Conclusion

In conclusion, the artificial reefs can be used to support small scale fishery as a fish aggregating device (FAD) in other areas of Palk Bay. The suitable sites should be selected only after conducting proper underwater scientific field survey and consultations with local fisher community. Artificial reef units should not be installed in and around natural seagrass bed areas and should be installed on the stable sandy sea floor, which is located about 7 - 8km away from Palk Bay shoreline. Trawler operations and any other fishing activities are already officially not permitted in artificial reef areas. However, some fishers still do cage fishing (Figure: 47) in artificial reef sites, which may affect the fish assemblages and damage reef units. During the study, it was also observed that a part of artificial reefs were damaged by dynamite fishing (Figure: 49 and 50) and trawlers (Figure: 46). So, there is a need for strict action in case of any destructive fishing activities noticed in artificial reef and seagrass bed areas in future. Palk Bay has been facing increased fishing pressure that also leads to cross border fishing problems. So, installation new artificial reefs in selected areas can be considered by local government, for improving small scale fishery, without disturbing natural seagrass beds of Palk Bay.

6. Tables

Table 1: Showing Mean abundance and size of fishes recorded in Artificial Reefs

	Tamil Name	English Name	Scientific Name	Family	Mean Abundance	Mean Size (cm)
1	ஊடகம்	Whipfin silver biddy/	*Gerres filamentosus* Cuvier, 1829	Gerreidae	7	11±
2	ஊளி மீன்	Banded barracuda	*Sphyraena jello*	Sphyraenidae	3	70±
3	கிளாத்தி மீன்	Red-tooth trigger fish	*Odonus niger*	Tetraodontoidei	3	18±
4	ஓரா மீன்	Streaked spinefoot	*Siganus javus*	Siganidae	2	22±
5	செப்பிலி மீன்	Bigeye snapper	*Lutjanus lutjanus*	Lutjanidae	3	30±
6	கொடுவா மீன்	Sea bass	*Lates calcarifer*	Centropomidae	1	80±
7	நெத்திலி மீன்	Indian anchovy	*Stolephorus indicus*	Engraulidae	8	8±
8	விளமீன்	Spangled emperor	*Lethrinus nebulosu*	Lethrinidae	1	37±
9	கிளிமீன்	Parrot fish	*Scarus ghobban*	Scaridae	5	45±
10	கீலி மீன்	Tiger Bass	*Terapon jarbua*	Terapontidae	11	12±
11	செங்கனி	Waigieu sea perch	*Psammoperca waigiensis*	Centropomidae	3	18±
12	களவா	Thorny cheek grouper	*Epinephelus diacanthus*	Serranidae	2	21±
13	காளா மீன்	Fourfinger threadfin	*Eleutheronema tetradactylum*	Polynemidae	2	11±
14	பருத்தி வெளமீன்	John's snapper	*Lutjanus johnii*	Lutjanidae	3	39±
15	பன்னா	Sin croaker	*Johnius dussumieri*	Sciaenidae	1	13±
16	குதிப்பு/சுதும்பு	False trevally	*Lactarius lactarius*	Lactariidae	4	15±
17	கிழங்கான்	Silver whiting	*Sillago sihama*	Sillaginidae	3	11±
18	வாவல்	White pomfret	*Pampus argenteus*	Stromateidae	2	22±
19	குமுளா	Faughn's mackerel	*Rastrelliger faughni*	Scombridae	2	29±
20	கூறல்	Blackspotted croaker	*Protonibea diacanthus*	Sciaenidae	1	44±

Table 2: Showing Mean abundance and size of fishes recorded in Artificial Reefs

No.	Tamil Name	English Name	Scientific Name	Family	Mean Abundance	Mean Size
1	ஊடகம்	Whipfin silver biddy/	*Gerres filamentosus Cuvier, 1829*	Gerreidae	4	8±
2	ஊசி கனவா	Indian squid	*Loligo duvaucelli*	Loliginidae	1	19±
3	ஓட்டு கனவா	Cuttlefish	*Sepia spp*	Sepiidae	1	35±
4	சீலா மீன்	Great barracuda	*Sphyraena barracuda*	Sphyraenidae	3	53±
5	ஓரா மீன்	Streaked spinefoot	*Siganus javus*	Siganidae	1	17±
6	செப்பிலி மீன்	Bigeye snapper	*Lutjanus lutjanus*	Lutjanidae	1	21±
7	கொடுவா மீன்	Sea bass	*Lates calcarifer*	Centropomidae	1	53±
8	கெடுத்தை மீன்	Spotted catfish	*Arius maculatus*	Ariidae	2	28±
9	முரல் மீன்	Flat needlefish	*Ablennes hians*	Belonidae	3	37±
10	நெத்திலி மீன்	Indian anchovy	*Stolephorus indicus*	Engraulidae	4	8±
11	சீலா மீன்	Great barracuda	*Sphyraena barracuda*	Sphyraenidae	2	45±
12	விளமீன்	Spangled emperor	*Lethrinus nebulosu*	Lethrinidae	2	26±
13	கீலி மீன்	Tiger Bass	*Terapon jarbua*	Terapontidae	33	8±
14	தாழஞ் சுறா	still to be identified			1	89±
15	செங்கனி	Waigieu sea perch	*Psammoperca waigiensis*	Centropomidae	2	32±

Table 3: Showing Mean abundance and size of fishes recorded in Artificial Reefs

No.	Tamil Name	English Name	Scientific Name	Family	Mean Abundance	Mean Size
1	ஓட்டு கனவா	Cuttlefish	*Sepia spp*	Sepiidae	1	28±
2	ஓரா மீன்	Streaked spinefoot	*Siganus javus*	Siganidae	3	15±
3	கெடுத்தை மீன்	Spotted catfish	*Arius maculatus*	Ariidae	4	26±
4	கீலி மீன்	Tiger Bass	*Terapon jarbua*	Terapontidae	48	7±

Table: 4. Showing Goodness of fit coefficients for all the three sites:

	A.R	S.B	A.B
R (coefficient of correlation)	0.946	1.000	0.847
R^2 (coefficient of determination)	0.896	0.999	**0.718**
R^2adj. (adjusted coefficient of determination)	0.166	0.993	-1.258
SSR	0.951	0.036	38.281

Table: 5. Showing Analysis of variance (A.R)

Evaluating (H0 = Y=Moy(Y)):					
Source	DF	Sum of squares	Mean square	Fisher's F	Pr > F
Model	7	8.172	1.167	1.228	**0.603**
Residuals	1	0.951	0.951		
Total	8	9.122			

Table: 6. Showing Analysis of variance (S.B)

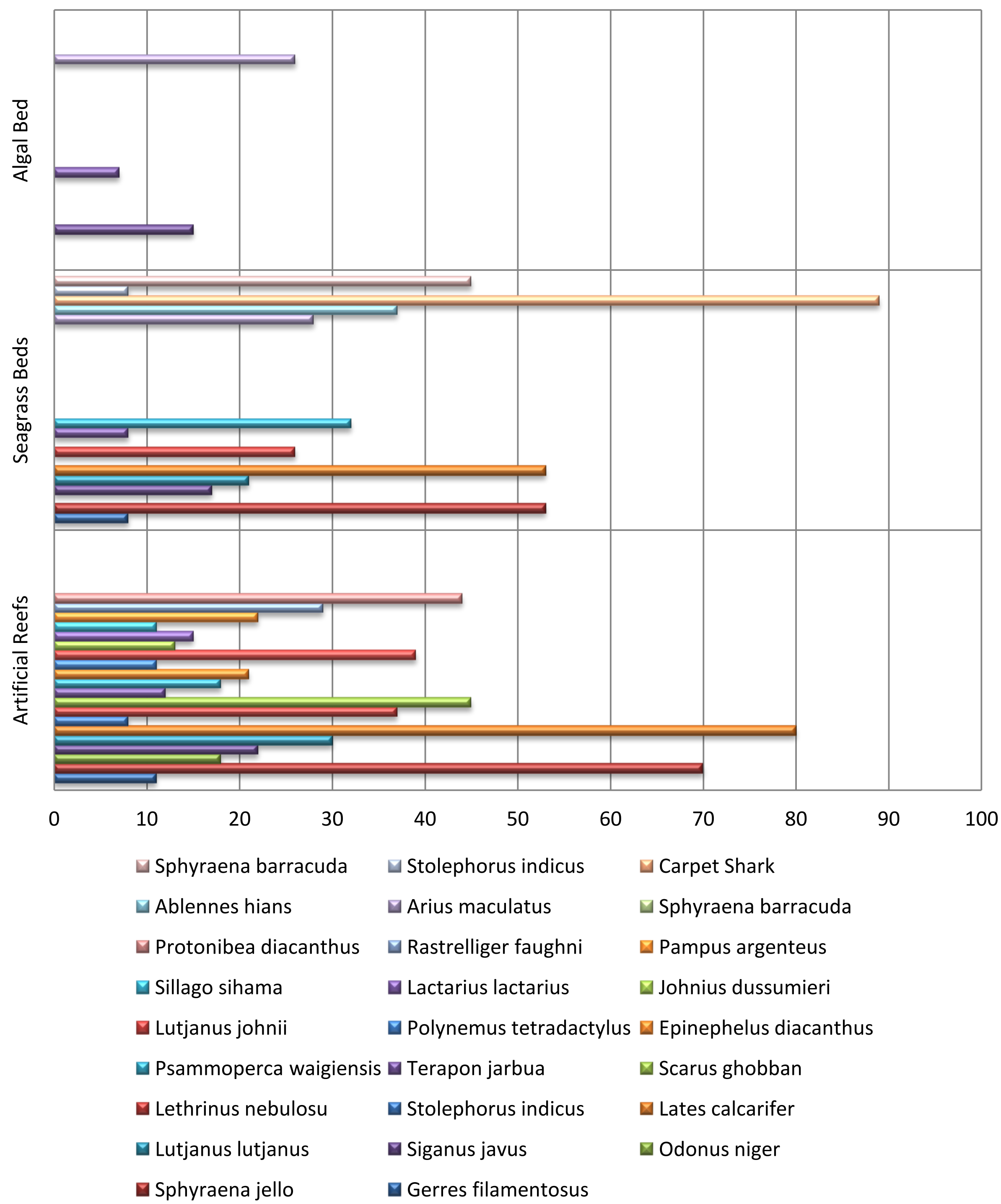
Source	DF	Sum of squares	Mean square	Fisher's F	Pr > F
Model	7	41.562	5.937	166.991	**0.060**
Residuals	1	0.036	0.036		
Total	8	41.598			

Table: 7. Showing Analysis of variance (A.B)

Source	**DF**	**Sum of squares**	**Mean square**	**Fisher's F**	**Pr > F**
Model	7	97.341	13.906	0.363	**0.859**
Residuals	1	38.281	38.281		
Total	8	135.622			

7. Figures

Fig:1. Mean Size of Fishes



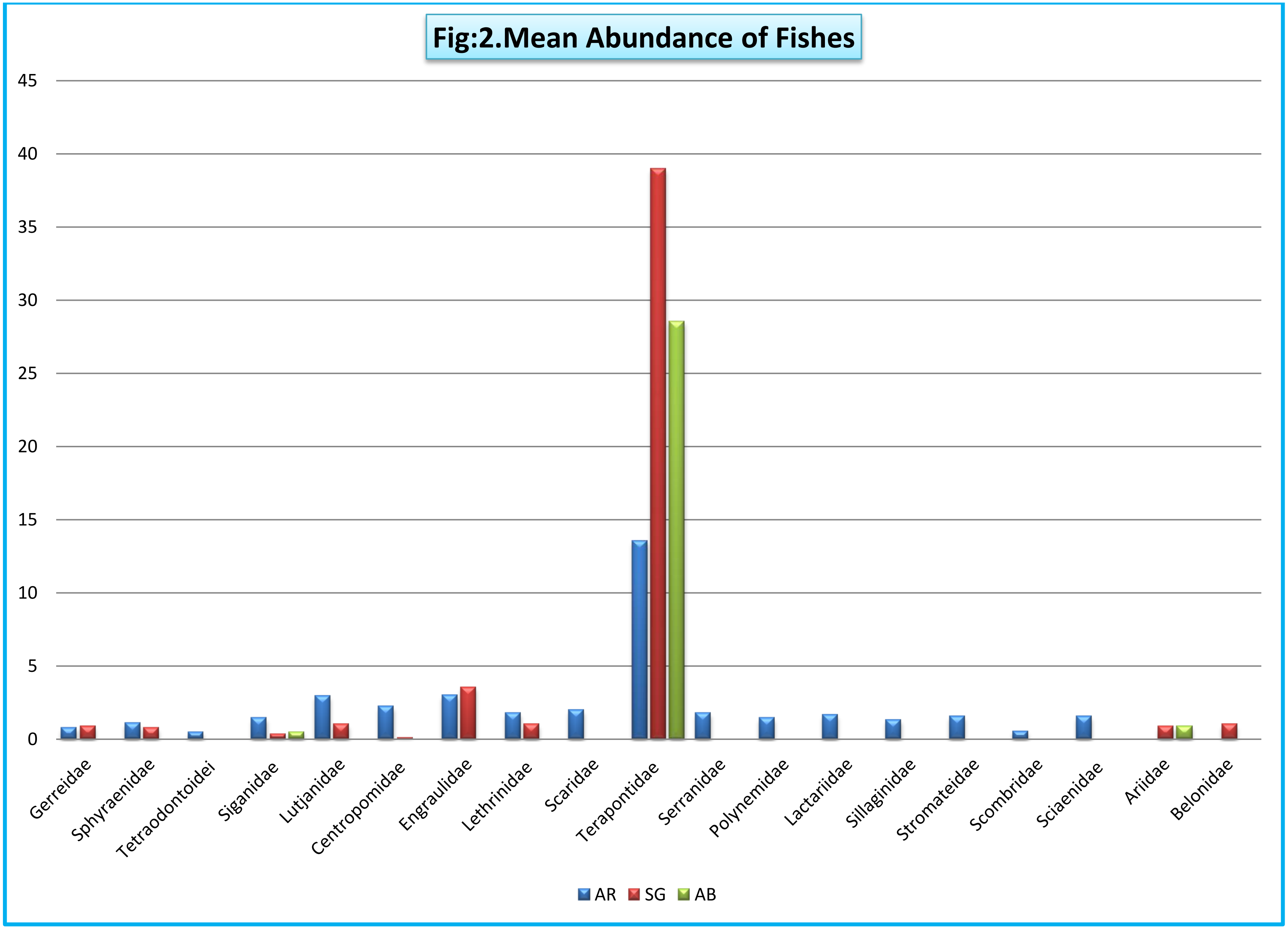
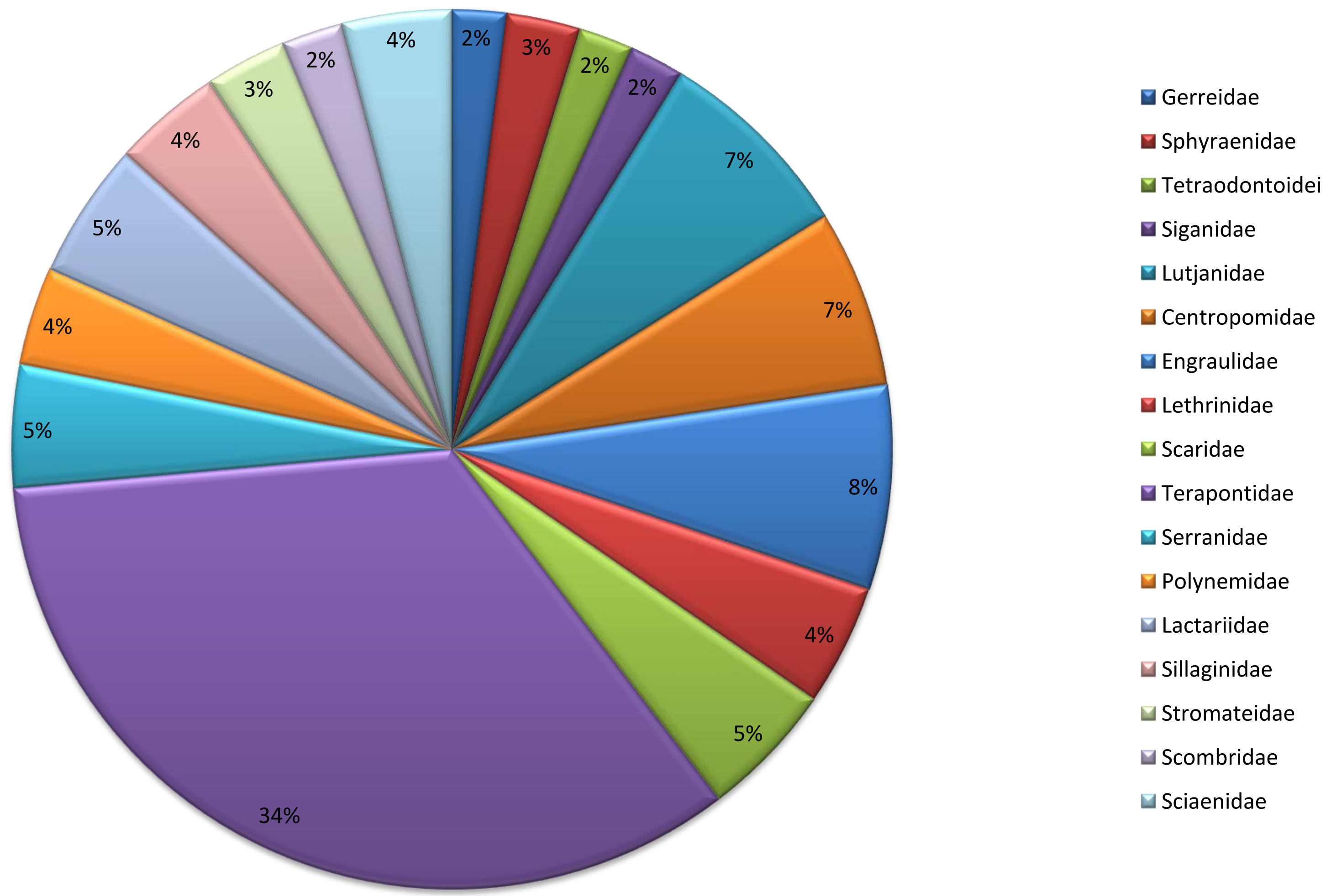


Fig:2.Mean Abundance of Fishes
45
40
35
30
25
20
15
10
5
0
Gerreidae
Sphyraenidae
Tetraodontoidei
Siganidae
Lutjanidae
Centropomidae
Engraulidae
Lethrinidae
Scaridae
Terapontidae
Serranidae
Polynemidae
Lactariidae
Sillaginidae
Stromateidae
Scombridae
Sciaenidae
Ariidae
Belonidae
AR
SG
AB

Fig:3. Percentage of Fish Families Recorded in Bait Video at Artificial Reef



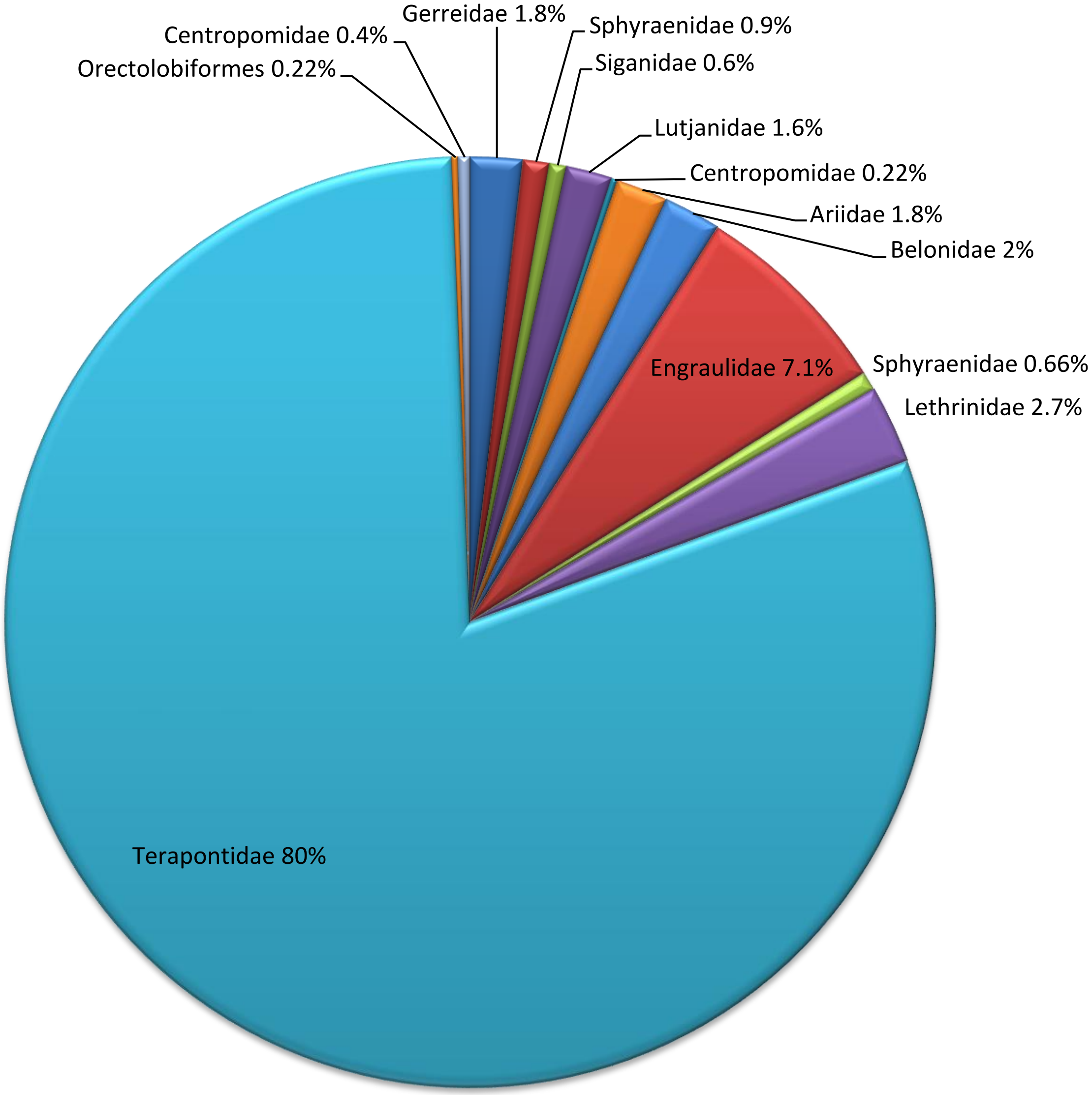


Fig:4. Percentage of Fish Families Recorded in Bait Video at Seagrass Beds

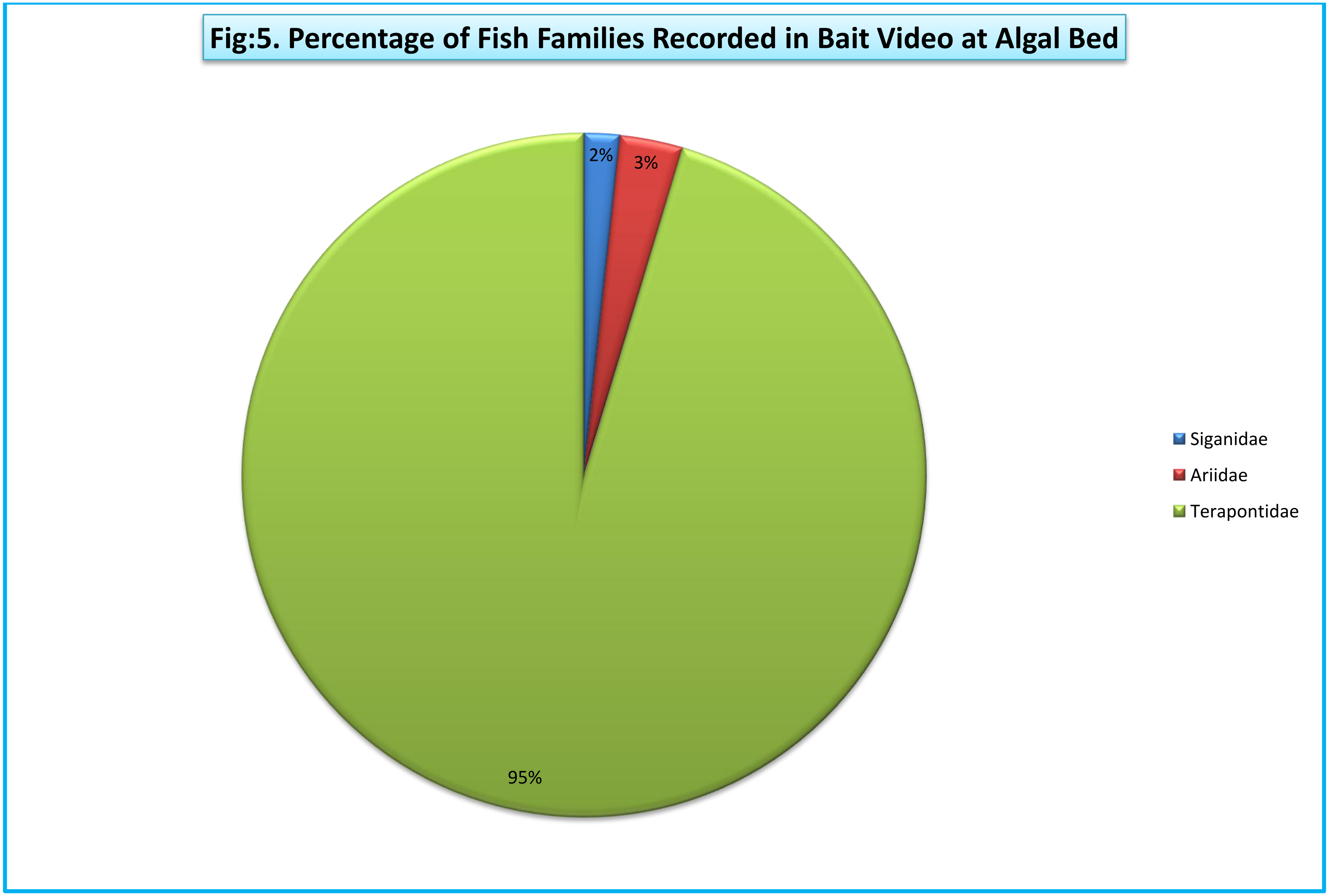


Fig:5. Percentage of Fish Families Recorded in Bait Video at Algal Bed
2%
3%
95%
Siganidae
Ariidae
Terapontidae

Fig:6. Mean Abundance of Cephalopods

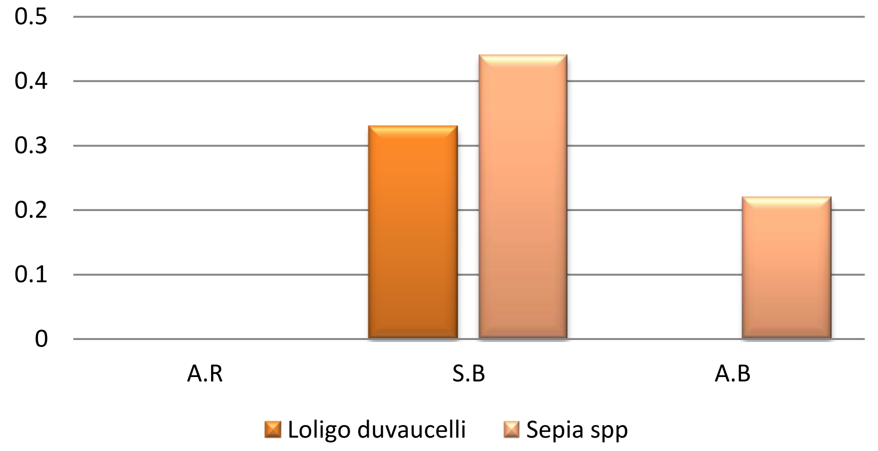


Fig:7. Mean Size of Cephalopods

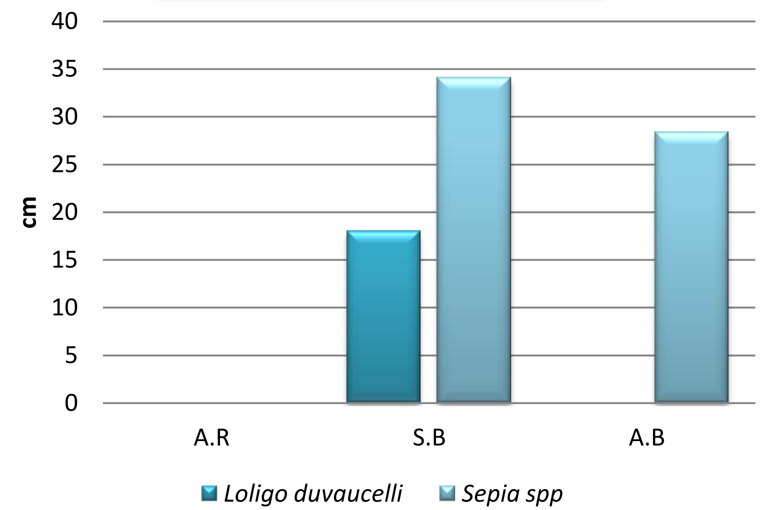


Fig:8. Atmospheric Temperature

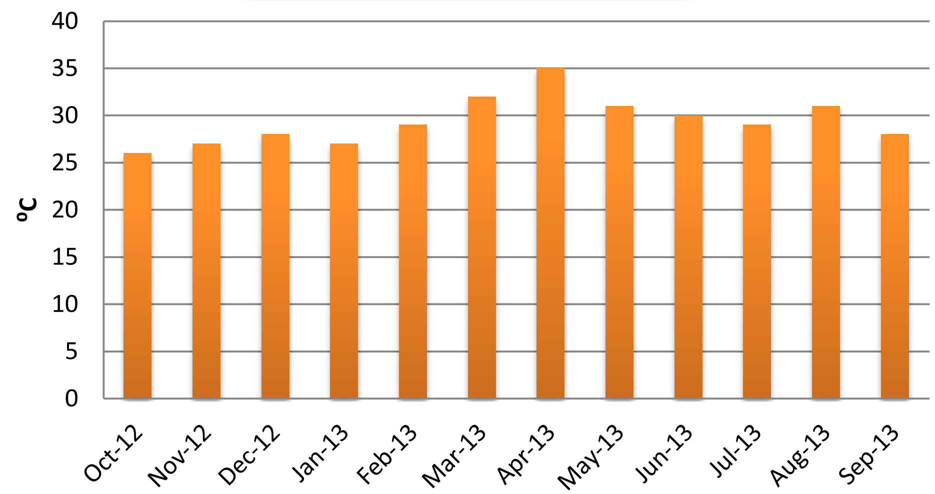


Fig:9. Water Temperature

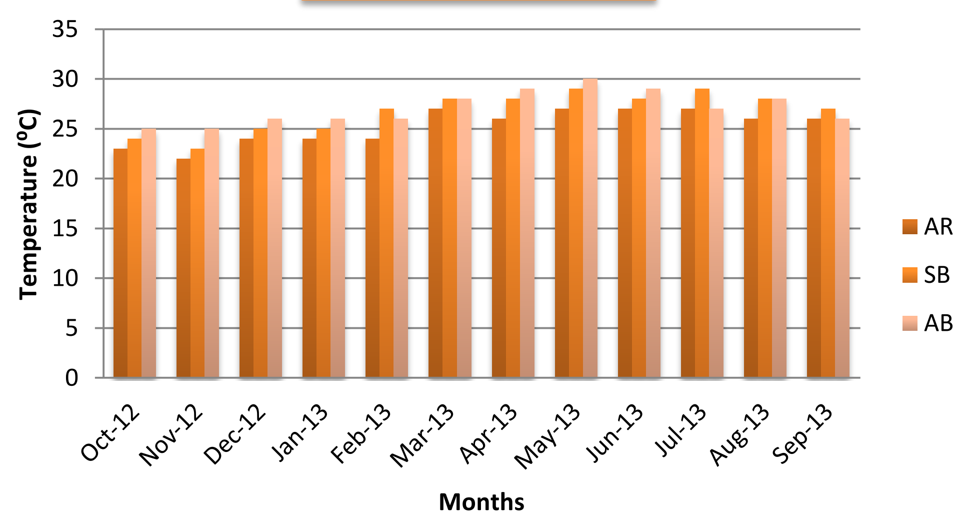


Fig:10. pH

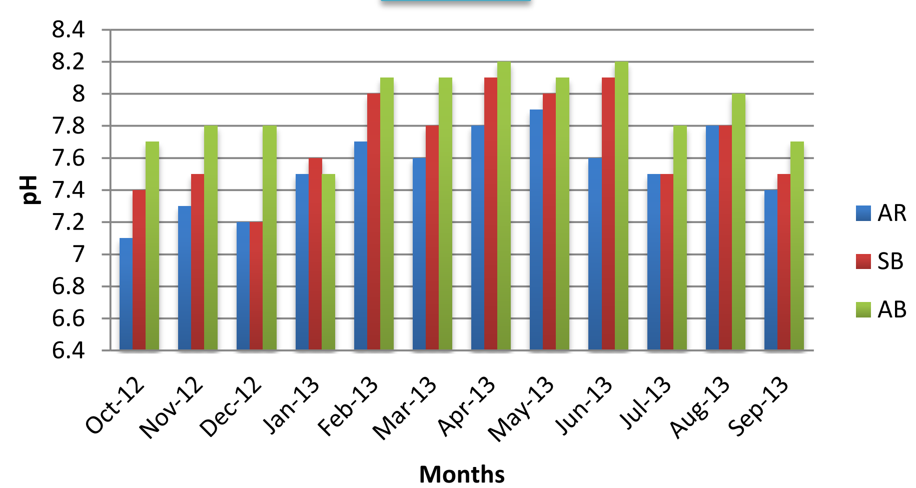


Fig:11. Salinity

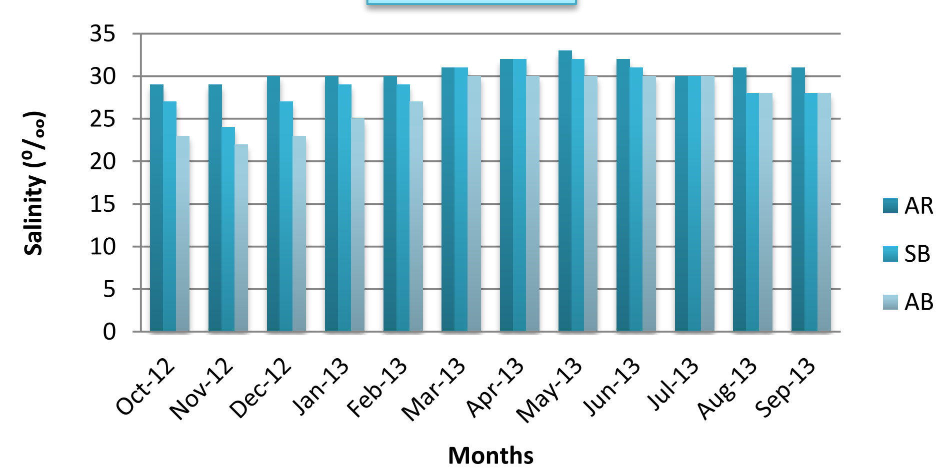


Fig:12. Fish Abundance (Artificial Reefs) / Standardized residuals

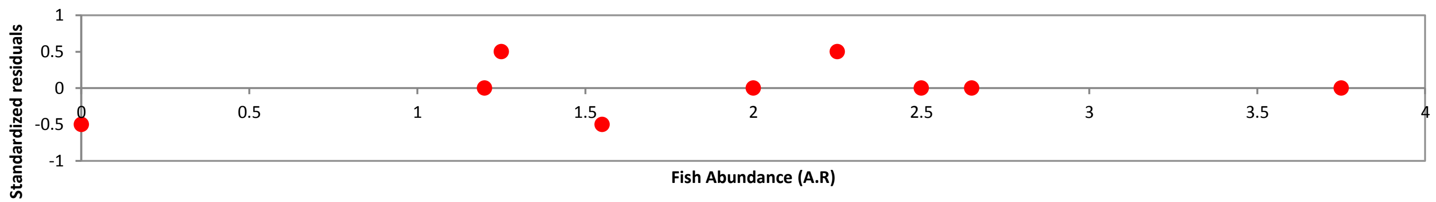


Fig:13. Fish Abundance (Seagrass Beds) / Standardized residuals

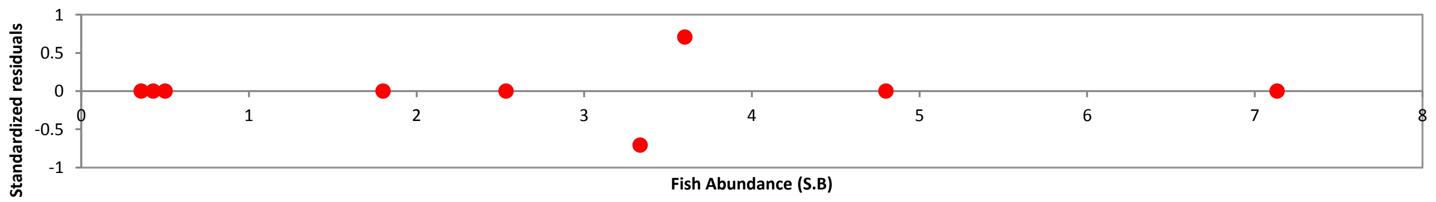
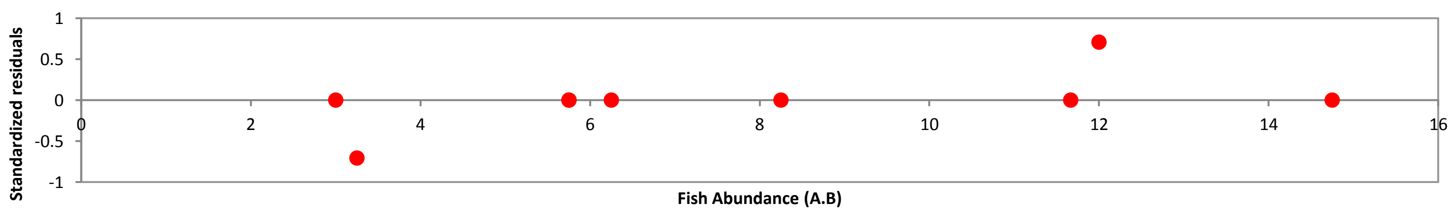


Fig:14. Fish Abundance (Algal Beds) / Standardized residuals



Analysis of Interactions between environmental factors and its influence on fish abundance in Artificial Reefs

Fig:15. Interaction plot between factors Water Temperature and pH

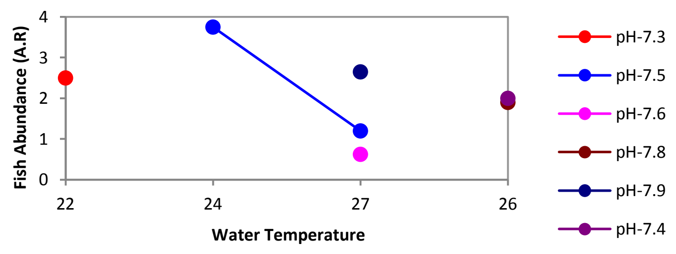


Fig:16. Interaction plot between factors Water Temperature and Salinity

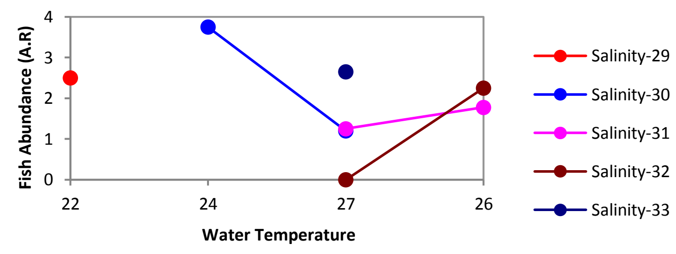


Fig:17. Interaction plot between factors pH and Water Temperature

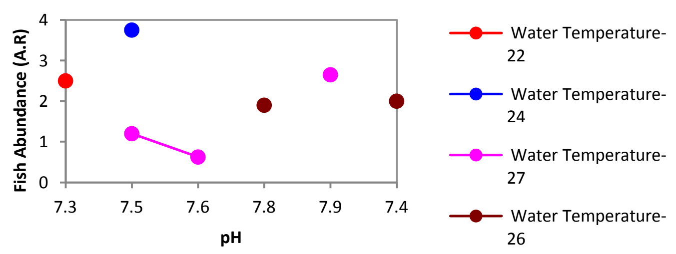


Fig:18. Interaction plot between factors pH and Salinity

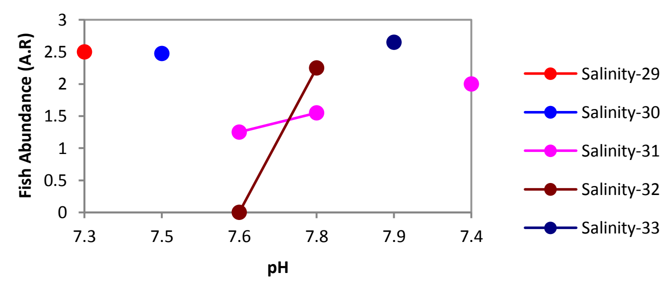


Fig:19. Interaction plot between factors Salinity and Water Temperature

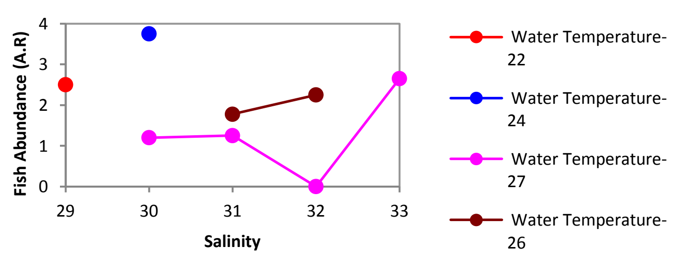
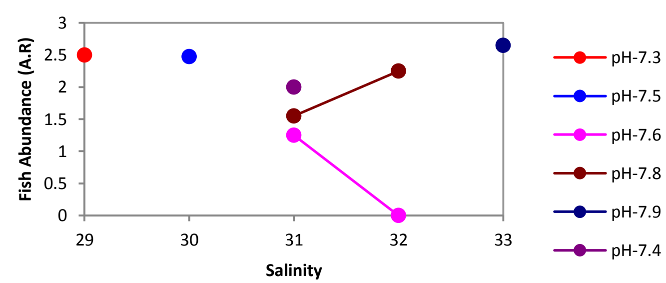


Fig:20. Interaction plot between factors Salinity and pH



Analysis of Interactions between environmental factors and its influence on fish abundance in Seagrass Beds

Fig:21. Interaction plot between factors Water Temperature and pH

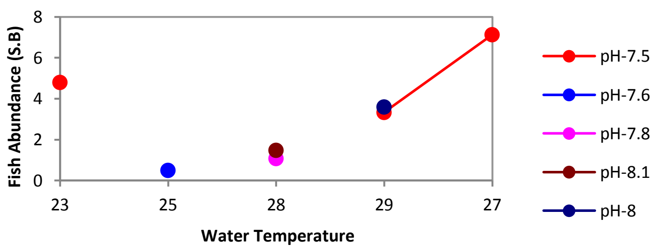


Fig:22. Interaction plot between factors Water Temperature and Salinity

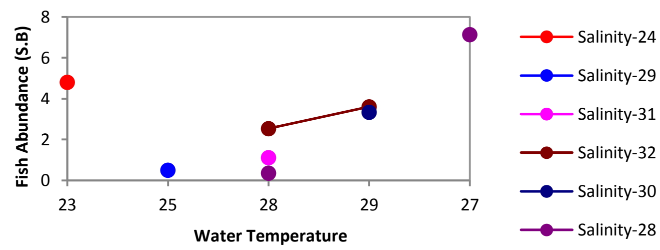


Fig:23. Interaction plot between factors pH and Water Temperature

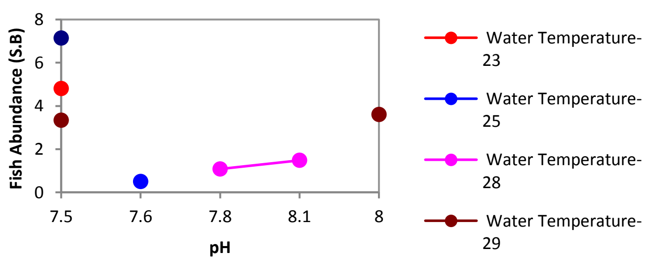


Fig:24. Interaction plot between factors pH and Salinity

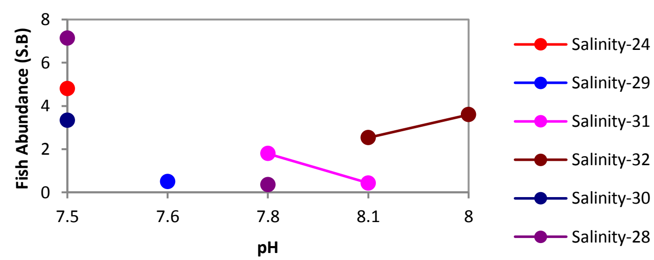


Fig:25. Interaction plot between factors Salinity and Water Temperature

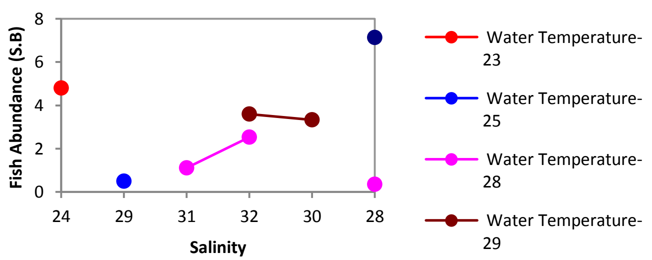
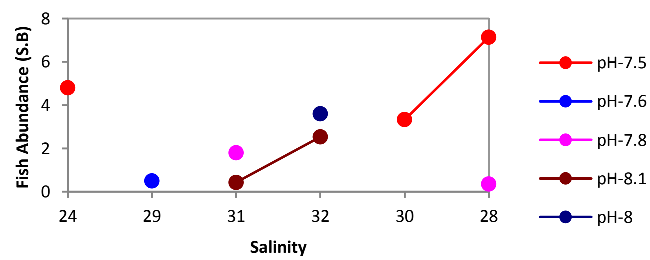


Fig: 26. Interaction plot between factors Salinity and pH



Analysis of Interactions between environmental factors and its influence on fish abundance in Algal Beds

Fig:27. Interaction plot between factors Water Temperature and pH

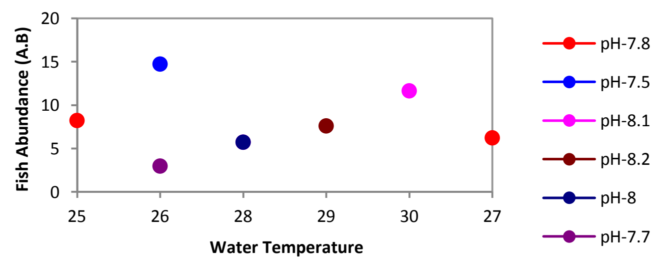


Fig:28. Interaction plot between factors Water Temperature and Salinity

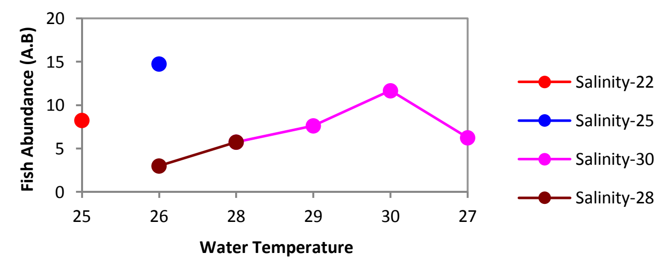


Fig:29. Interaction plot between factors pH and Water Temperature

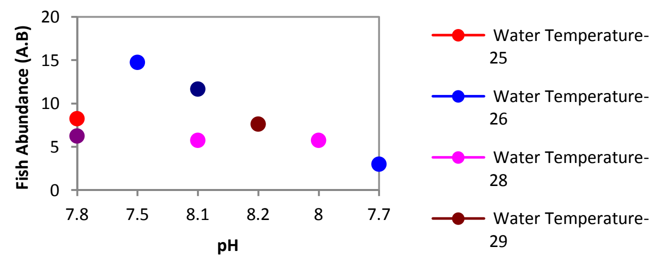


Fig:30. Interaction plot between factors pH and Salinity

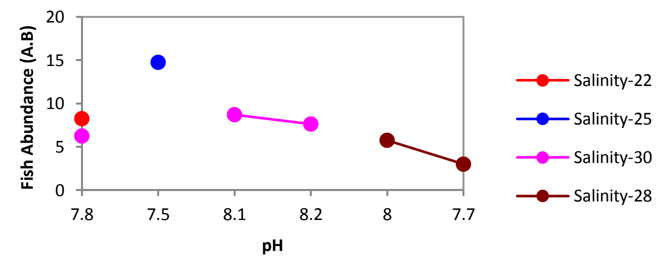


Fig:31. Interaction plot between factors Salinity and pH

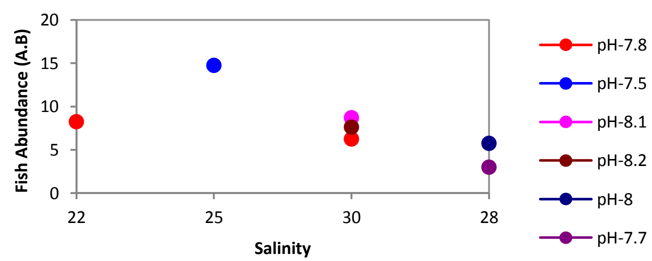


Fig:32. Interaction plot between factors Salinity and Water Temperature

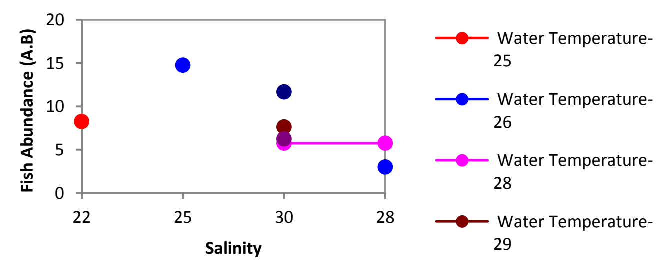


Fig: 33. Showing Palk Bay

Fig:34. Showing Artificial Reef locations in northern Palk Bay

Fig: 35. Diver is fixing bait video system on the seafloor.

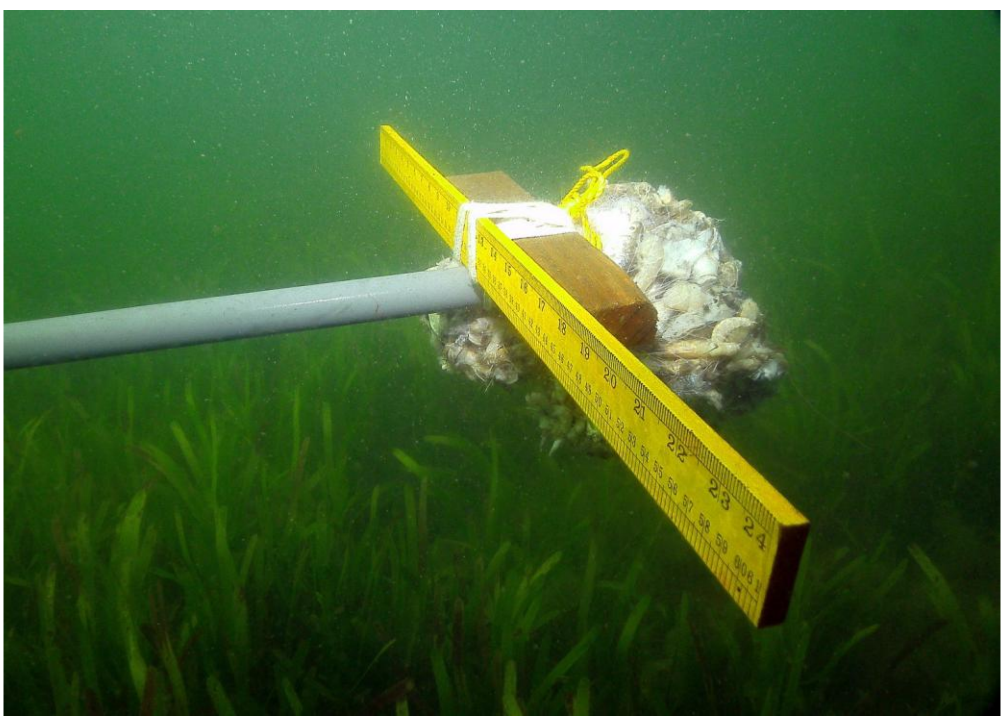


Fig: 36. Adjusting bait video camera view

Fig: 37. Water sampling

Fig:38. Fish bait tied on the tip of iron rode, a wooden scale is fixed to measure the size of the

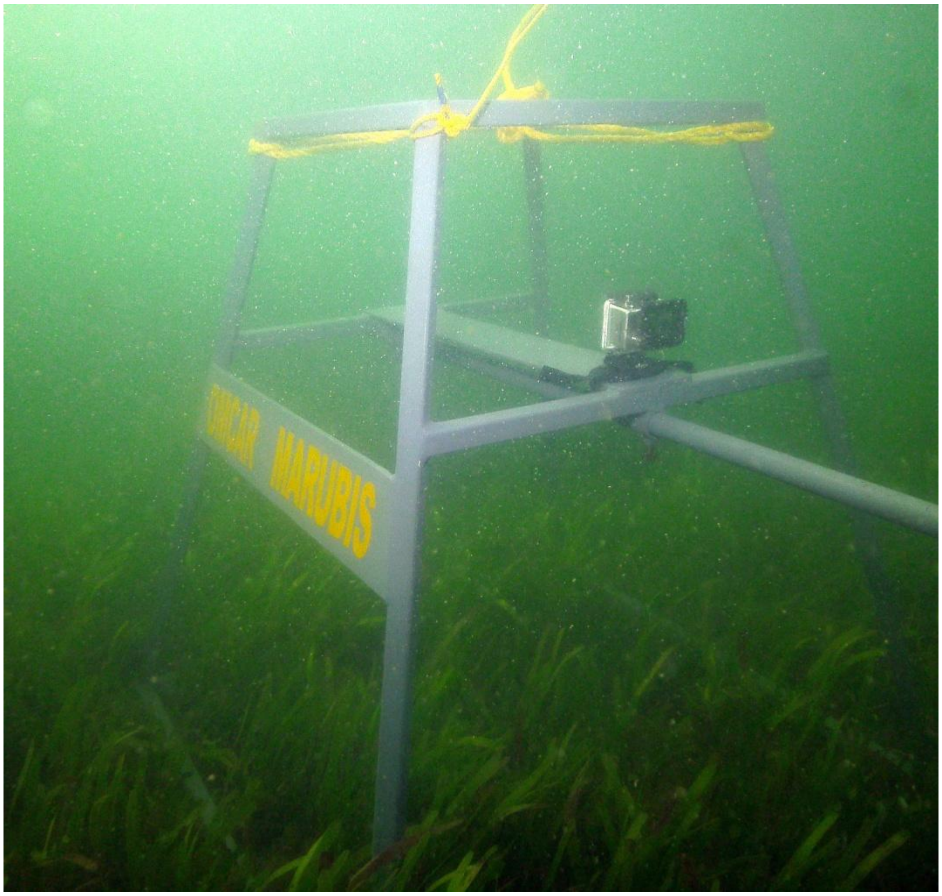


Fig: 39. Bait Video System fixed on the sea grass bed

Fig: 40. Gopro HD camera used in bait video system

Fig: 41. Fishes attracted to Bait Video System fixed on the algal bed

Fig: 42. Bait Video System being deployed from boat

Fig: 43. "Gable" shaped Artificial Reefs (side view)

Fig: 44. Assemblages of different species of fishes in artificial reef site

Fig: 45. ‘Ring’ shaped artificial reef

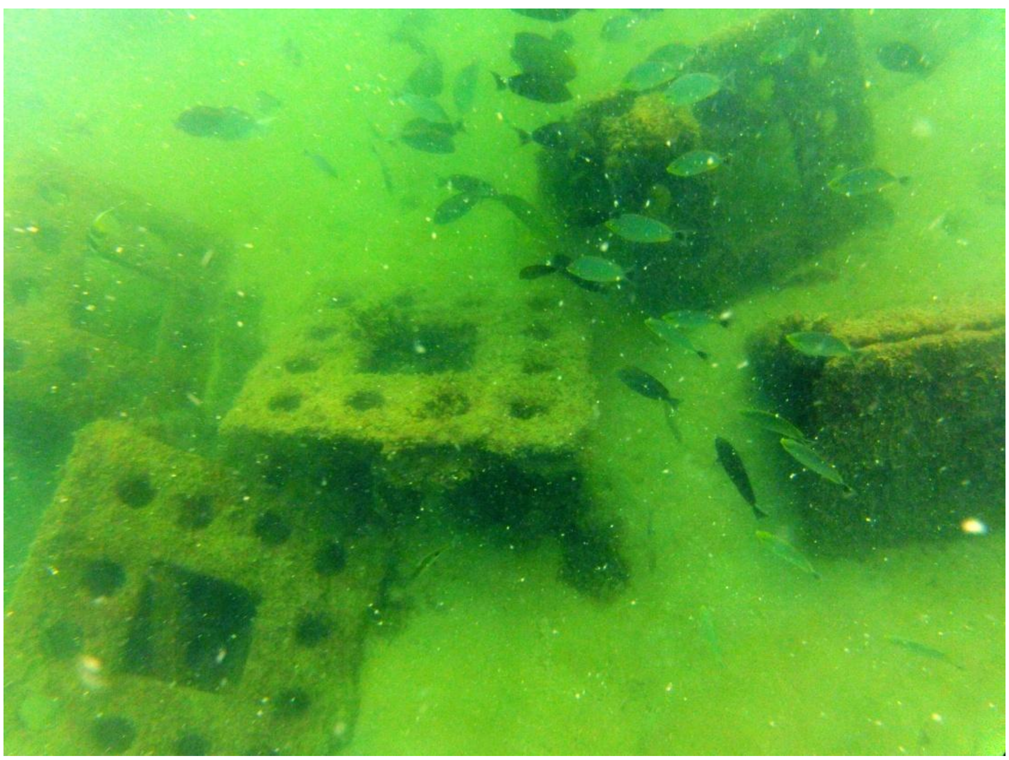


Fig: 46. Artificial reefs damaged by trawlers

Fig: 47. Cage fishing is being practiced in artificial reef site by some fishers, which was checked by our team.

Fig: 48. Grouper fishes (*Epinephelus diacanthus)* found in artificial reefs

Fig: 49. Artificial reef damaged by dynamite fishing (Jan. 2013)

Fig: 50. A dead trigger fish – victim of dynamite fishing in artificial reefs (Jan. 2013)

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